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CONVERTER SYSTEM, METHOD, AND CONVERTER

Background of the Invention

The present invention relates to a converter system, method, and a converter.

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Converters for powering electric motors are well-known. In this context, an intermediate circuit voltage provided for powering an inverter is mostly generated from an a.c. network voltage, using a rectifier. During regenerative operation, the energy generated is consumed by a braking resistor, which is supplied current by a brake chopper, i.e. an electronic circuit breaker. The heat generated at the braking resistor must be dissipated, for which appropriate space is provided, in particular for air flow, as well. In addition, a converter is necessary for each electric motor.

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Therefore, the object of the present invention is to provide an option for powering a plurality of electric motors in a cost-effective manner, the intention also being that the means for attaining the object be designed to be as compact as possible.

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In the case of the converter system, the object of the present invention is achieved according to the features specified in Claim 1 or Claim 21; in the case of the method, the object of the present invention is achieved according to the features specified in Claim 24; and in the case of the converter, the object of the present invention is achieved according to the features specified in Claim 27.

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In the case of the adapter device, the essential features of the present invention are that the converter system includes

- at least one supply module, which provides a unipolar, intermediate circuit voltage;
- one or more drive modules, which may be powered by the intermediate circuit voltage and each include at least one inverter for powering at least one electric motor, in particular a synchronous motor or an asynchronous motor; and
- at least one buffer module for storing energy.

In this context, it is advantageous that the buffer module allows energy generated by the drive modules during regenerative operation to be temporarily stored. In particular, the buffer module may be supplied with energy for periods of time, especially during regenerative operation of at least one drive module, and stored energy may be subsequently released by the buffer module to at least the drive modules. The modular construction is a further advantage, for in the case of the converter system, the modules are combined according to the application, and therefore, the variety of components is reduced in comparison with a system made of separate converters. Modules in regenerative operation and modules in motive operation are connected by the intermediate circuit and may therefore balance out energy mutually. In addition, the buffer module does not load the network, because current is only fed to the capacitor of the buffer module when a first critical value of the intermediate circuit voltage is exceeded. Thus, current is supplied in a controlled manner.

In a preferred variant, at least one supply module includes a rectifier for generating d.c. voltage from an a.c. voltage, in particular from a three-phase a.c. network voltage. In this context, it is advantageous that the converter system may be powered by a customary industrial or domestic a.c. voltage network.

In a preferred variant, at least one supply module includes a feedback unit, or a feedback unit is connectible as a module

to the intermediate circuit voltage and the a.c. voltage, in particular to a three-phase a.c. network voltage, to provide feedback from the intermediate circuit into the network. In this context, it is advantageous that energy, which is generated during regenerative operation and cannot be stored by the buffer module, may be fed back into the network. Therefore, the energy costs may be reduced.

In a preferred variant, at least one supply module includes an electronic circuit breaker, which allows passage of or blocks current induced by the intermediate circuit voltage and in the direction of a device connected to an output of the supply module, as a function of the activation of the electronic circuit breaker. In this context, it is advantageous that the electronic circuit breaker may be used to control the current for a braking resistor and/or for a buffer module and therefore releases energy to the buffer module as a function of the intermediate circuit voltage.

In a preferred variant, the drive circuit of the electronic circuit breaker is connected to a means for measuring the intermediate circuit voltage. In this context, it is advantageous that the activation may be designed to be a function of the intermediate circuit voltage, in particular, that the switching or a pulsed operating mode of the switch may therefore be implemented in response to critical values being exceeded.

In a preferred variant, the buffer module includes a capacitor, of which the capacitance is greater than the sum of that of all the capacitors to which the intermediate circuit voltage is directly applied. In this context, it should be pointed out that the capacitor of the buffer module is not directly connected to the intermediate circuit, but via further devices, such as diodes. In the case of this value of the capacitance, it is advantageous that a braking resistor having high temperatures and requiring a large unit volume, in

particular for cooling, may be dispensed with. In addition, the energy is not subsequently converted into heat but retained by capacitors of the buffer module in the form of electrical energy, which may be fed back to the drive modules connected to the intermediate circuit. Consequently, the energy consumption is decreased, and the energy costs are reduced.

In a preferred variant, the buffer module includes a capacitor, of which the capacitance is dimensioned so that during motive operation at nominal load, with the capacitor directly connected to the intermediate circuit, the a.c. voltage component of the intermediate circuit voltage would be less than half as large as the a.c. voltage component with the capacitor not connected in this manner. This characteristic is only used for defining the value of the capacitance of the capacitor. In the variant according to the present invention, the capacitor of the buffer module is not directly connected to the intermediate circuit, for it is charged or discharged by further devices, as a function of the intermediate circuit voltage. In the case of this sizing, it is advantageous that the buffer module may be designed to have a capacitor, of which the unit volume is small in relation to the sum of the volumes of the intermediate circuit capacitors of the separate converters corresponding to the converter system. In particular, a more cost-effective foil capacitor may be used. Thus, the unit volume of the overall converter system is low, and, all in all, the converter system may be inexpensively manufactured, in particular when using a supply module having feedback.

In a preferred variant, a buffer module is provided, which is connected to an output of the supply module and includes a capacitor, of which the charging current may be influenced and/or controlled by at least the electronic circuit breaker. In this context, it is advantageous that the capacitor may be sized according to the application, and that energy from the

capacitor may be fed back to drive modules or optionally to a supply module containing a network feedback unit.

5 In a preferred variant, buffer module PM includes at least one electrolytic capacitor. In this context, it is advantageous that the buffer module may be provided with high capacitances.

In the case of the converter system, the essential features of the present invention are that, to form the converter system,

- 10 - at least one supply module, which provides a unipolar, intermediate circuit voltage;  
- one or more drive modules, which may be powered by the intermediate circuit voltage and each include at least one inverter for powering at least one electric motor, in particular a synchronous motor or an asynchronous motor; and  
15 - at least one buffer module for storing energy

are at least electrically connectible via a bus system, the bus system including

- 20 - at least two power cables (+,-) for carrying the intermediate circuit voltage; and  
- a power cable BRC for electrically connecting the supply module(s) to the buffer module(s).

25 In this context, it is advantageous that the bus system may be configured so that different modules are connectible and connected to the intermediate circuit voltage for removing energy or supplying energy to the intermediate circuit.

30 In a preferred variant, the modules, such as the buffer module or drive modules, the supply module, and, if applicable, further modules each have the same kind of interface for electrical and mechanical connection to the bus system. In particular, the interface is constructed in the same manner in  
35 all of the modules. In this context, it is advantageous that a system is provided which is highly flexible and may be

adapted to the specific applications. For example, a feedback module may be added to an existing converter system, in order to save energy, or a buffer module or a larger buffer module may be connected. In addition, different drive modules may be connected.

In the case of the method, the essential features of the present invention are that, in order to operate a buffer module in a converter system including

- at least one supply module VM, which provides a unipolar, intermediate circuit voltage,
- one or more drive modules AM, which may be powered from the intermediate circuit voltage and each include at least one inverter for powering at least one electric motor, and
- at least one buffer module PM for storing energy,

where

- the intermediate circuit voltage is measured, and
- in response to a first critical value of the intermediate circuit voltage being exceeded, buffer module PM is supplied with energy, when the overall regenerative power of first drive modules exceeds the motive power of second drive modules,

the buffer module feeds back energy to the modules powered by the intermediate circuit voltage, when the total motive power of drive modules exceeds the regenerative power. In this context, it is advantageous that the intermediate circuit voltage is monitored, several drive modules being connected which may transmit energy via the intermediate circuit. Thus, the number of cases in which the intermediate circuit voltage exceeds a critical value is reduced. In addition, a single buffer module, which may be selected to be smaller than the sum of the capacitances of the intermediate circuit capacitors of corresponding, separate converters when appropriately dimensioned, may be used for several drive modules in this manner. This reduces the costs and the unit volume. Moreover, a single circuit breaker is sufficient for

switching, and it is sufficient to measure the intermediate circuit voltage only once for several drive modules.

5 In the case of a second critical value of the intermediate circuit voltage being exceeded, a preferred variant provides for current to flow through a braking resistor to dissipate energy, when the total regenerative power of first drive modules exceeds the motive power of second drive modules. In this context, it is advantageous that, in a corresponding application case, the converter system may additionally be provided with a module that includes a braking resistor, and that the intermediate circuit voltage may therefore be kept in the permissible range. In this connection, the critical value for the switching of the braking resistor may be designed to be different from the critical value for the switching of the buffer capacitor. Therefore, in a particularly advantageous manner, energy may be stored in the buffer module in the case of short-term regenerative operation, and consumed in the braking resistor in the case of long-term regenerative operation.

20 In another preferred variant, the second and first critical values are identical. In this context, it is advantageous that the method may be implemented in a particularly simple manner.

25 Further advantageous developments are yielded from the dependent claims.

## List of Reference Numerals

	VM	supply module
	AM	drive module
5	PM	buffer module
	PVM	integrated buffer/supply module
	M	electric motor
	BRC	electrical connecting point
10	1	rectifier
	2,23	means for measuring voltage
	3	drive circuit
	10	charging means
	32	drive circuit
15	33	means for measuring current
	C1	capacitor
	C2	capacitor
	C3	capacitor
20	D1,D2,D3	diodes
	T1,T2	electronic circuit breaker



The present invention shall now be explained in detail with reference to the figures:

Shown in Figure 1 is a converter system of the present invention, where a supply module VM contains a rectifier 1, which generates an intermediate circuit voltage (reference symbols +, -) from a three-phase a.c. network voltage, i.e. three-phase voltage, a capacitor C1 being provided for reducing electromagnetic interference. The intermediate circuit voltage is directly applied to capacitor C1.

Means 2 for measuring voltage are connected to drive circuit 3 of electronic circuit breaker T1, which may therefore be reset from the blocked state into the conductive state in response to the intermediate circuit voltage exceeding a critical value. Capacitor C2 may be charged via this electronic circuit breaker T1.

Intermediate circuit voltage (+, -) also powers drive modules AM, which each include converters for powering electric motors, in particular asynchronous motors or synchronous motors. Also integrated into drive modules AM are electronic circuits, which are used for implementing open-loop and/or closed-loop control methods. Therefore, drive modules AM are essentially like converters, except for rectification and intermediate circuit capacitor C1. In addition, the buffer module and, if indicated, further modules, such as the feedback module or a module containing a braking resistor, are also not in the drive module.

Capacitor C2 is charged and the maximum charging current is therefore limited via charging means 10, which, in a first exemplary embodiment of the present invention, may be implemented as an electrical resistor.

In other exemplary embodiments of the present invention, inductive elements or combinations of inductive elements and electrical resistors are provided as charging means 10.

5 The capacitance of capacitor C1 is selected to be so low that, during rated, motive operation, and in the case of a disconnected buffer module, the alternating component of the intermediate circuit voltage is essentially equal to the alternating component that would be present if capacitor C1  
10 were not present. The capacitor C1 is not implemented in the form of an electrolytic capacitor, but may be implemented as, e.g. a foil capacitor. In the case of a connected buffer module in rated operation, the alternating component of the intermediate circuit voltage essentially does not change, as  
15 long as all of the drive modules are in motive operation. Only when the intermediate circuit voltage exceeds a first critical value as a result of regenerative operation, is the buffer module charged with energy and the energy fed back into the intermediate circuit after the end of regenerative  
20 operation. In the case of a 400 V three-phase network customary in industry, this value is over 600 V, e.g. advantageously 800 V or more.

Capacitor C2 is designed as an electrolytic capacitor. The  
25 magnitude of its capacitance is such that, in the event of capacitor C1 being replaced by C2, the intermediate circuit voltage would be smoothed out in such a manner, that the alternating component would be less than half as large as in the aforementioned case. However, this direct connection with  
30 the intermediate circuit would load the network, since large charging currents are generated in the case of an uncharged capacitor. In particular, it would then also be necessary to limit the charging current, e.g. with the aid of a charging resistor. In the present exemplary embodiment of the present  
35 invention, capacitor C2 is not directly connected to the intermediate circuit voltage, but only indirectly connected to it via further devices, such as via charging means 10 and the

electronic circuit breaker. In other specific embodiments of the present invention, capacitor C2 is connected to the intermediate circuit voltage by other or further means, but never directly.

5 In the exemplary embodiment according to Figure 1, the capacitor is supplied with energy in regenerative operation, when the intermediate circuit voltage has exceeded a critical value. When several drive modules are connected, there are  
10 operating states in which a portion of the drive modules are regeneratively operated and another portion motively operated. Of course, it is important whether on the whole, energy is supplied to the intermediate circuit, i.e. the intermediate circuit voltage increases, or energy is removed from the  
15 intermediate circuit.

In Figure 1, the electrical connecting point is denoted by reference symbol BRC. Buffer module PM having charging means  
20 10 is connected to this.

20 Diode D1 has the function of protecting the components, in particular electronic circuit breaker T1, diode D1 acting as a freewheeling diode for charging means 10. Diode D2 allows the stored energy of capacitor C2 to be released to the  
25 intermediate circuit while it discharges, in that current flows through diode D2.

A converter system of the present invention having two drive modules is shown in Figure 2. The intermediate circuit,  
30 including the two lines + and - for the intermediate circuit voltage and line BRC for conducting buffer current through to the buffer module, is designed as a bus system to which the drive modules are connected by their respective interfaces.

35 Therefore, to form the converter system,  
- at least one supply module VM, which provides a unipolar, intermediate circuit voltage,

- one or more drive modules AM, which may be powered by the intermediate circuit voltage and each include at least one inverter for powering at least one electric motor, in particular a synchronous motor or an asynchronous motor; and  
5 - at least one buffer module PM for storing energy may be electrically and mechanically connected via the bus system, the bus system including  
- at least two power cables (+,-) for carrying the intermediate circuit voltage; and  
10 - a power cable BRC for electrically connecting the supply module(s) to the buffer module(s).

In this context, the bus system is advantageously implementable as a rail system, into which modules are  
15 insertable. To that end, the modules, such as buffer module PM or buffer modules, drive modules AM, supply module VM, and, if applicable, further modules each have an interface for electrical and mechanical connection to the bus system. In particular, this interface is constructed in the same manner  
20 in all of the modules. Instead of a rail system, bus systems operating in the same manner may also be used. However, a bus system, which is suitably constructed for receiving the above-mentioned and, in each case, the identically stamped interface at various discrete positions or even an infinite number of  
25 positions, may be used in a considerably advantageous manner.

In a further exemplary embodiment of the present invention, the supply module may include a network feedback unit. In another exemplary embodiment of the present invention, the  
30 network feedback unit may also be constructed as an independent module having, in turn, the same kind of interface for connection to the bus system.

In particular, the method of the present invention for  
35 directing energy from the intermediate circuit to a capacitor having a large capacitance may also be realized with the aid of a single converter.

Shown in Figure 3 is an integrated buffer/supply module PVM, in which the characteristics of supply module VM and buffer module PM are included. In addition, further advantageous characteristics are realized in this integration:

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Means 23 for measuring the intermediate circuit voltage and means for measuring the intermediate circuit current 33 are connected to drive circuit 3 for electronic circuit breaker T1. Therefore, the intermediate circuit current may also be considered during the triggering of electronic circuit breaker T1. In particular, a value of the loading of electronic circuit breaker T1 is ascertainable from these measured values of intermediate circuit voltage and intermediate circuit current, and the electronic circuit breaker may therefore be protected from overload. A further advantageous result of this is that inductor 10 may be sized to be the smaller, because the maximum expected currents for inductor 10 may be co-determined by switch T1.

20 The determination of the intermediate circuit current is also used for another purpose, namely for the overload protection of buffer/supply module PVM, i.e. in particular for the supply module part and the charging of the buffer.

25 Capacitor C3 is designed as an intermediate circuit capacitor. In further exemplary embodiments of the present invention, it may be implemented, in particular, as a cost-effective film capacitor and not as an electrolytic capacitor.

30 During regenerative operation, the intermediate circuit voltage increases until the voltage threshold value of drive circuit 3 is reached. When this value is exceeded, the electronic circuit breaker is reset to the conductive state by drive circuit 3. Therefore, the current for charging capacitor C2 flows through inductor 10 and is measured by means for measuring intermediate circuit current 33. If the current value determined in this manner reaches a critical

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value, electronic circuit breaker T1 is switched off. The charging current for capacitor C2 then continues to flow through inductor 10 and freewheeling diode D1 until the energy of the coil has essentially gone over to the capacitor.

5 During the described charging cycle, the intermediate circuit voltage decreases a little until electronic circuit breaker T1 is switched off. After the switching-off point, the intermediate circuit voltage increases again and the described charging cycle is repeated.

10 Means for measuring voltage 23 provide a second, further stepped-down value, which is a function of the intermediate circuit voltage and is transmitted to drive circuit 32 of electronic circuit breaker T2. At their inputs, drive  
15 circuits 3 and 32 have the same threshold voltage values, as a function of which electronic circuit breakers T1 and T2 are activated. This allows the buffer capacitor, i.e. capacitor C2, to initially be charged in a simple manner, and then allows the electronic circuit breaker to be switched into a  
20 conductive state only in response to a further increase in the intermediate circuit voltage, so that intermediate circuit current is drawn off by braking resistor BRC. Consequently, the braking resistor connected to outer terminals BRC may be supplied with energy as a function of the intermediate circuit  
25 voltage. A freewheeling diode D3 is connected in parallel with braking resistor BRC, since as a result, braking resistors, which have leads and have not only ohmic components but also inductive components, may also be used.

30 In further exemplary embodiments of the present invention, buffer/supply module PVM is designed so that terminals BRC are integrated and the braking resistor is likewise situated in the interior of buffer/supply module PVM.